THE ORIGIN OF THE CAVES AT PUT-IN-BAY, OHIO.

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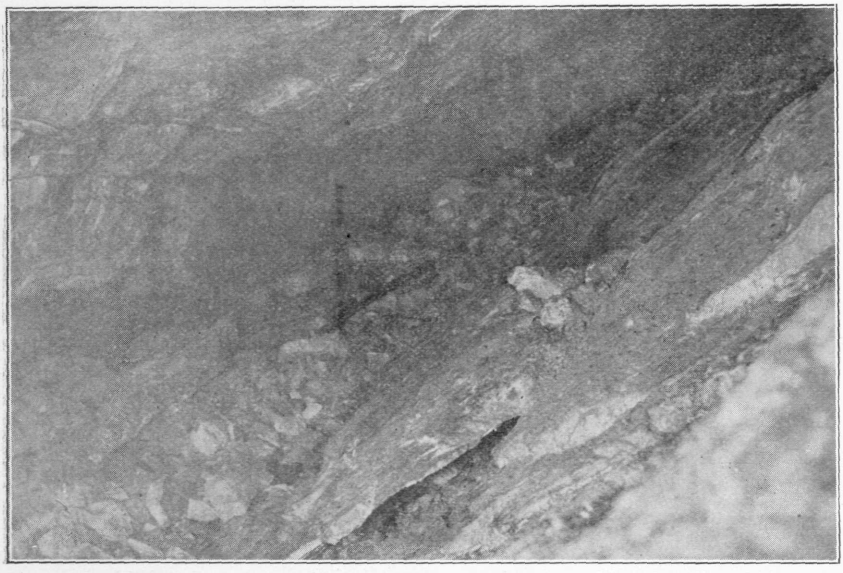
Certain features of the caves on Put-In-Bay Island are so unusual and so different from the ordinary solution cavern as to be apparent to the most casual observer. The absence of rounded forms, the sub-angular appearance of floor and roof, the similarity between depressions in the floor and protuberances on the roof, or vice-versa, impress even the tourist. The caves at Greenfield, Ohio, occur in rock of almost identical lithology—in fact, in the same formation though in a different member. Yet the Greenfield Caves consist of narrow, winding passages, often on two or three separate levels—the true type of caves produced by solution. At Put-In-Bay the rooms are cavernous—low, nearly as broad as long, and without passages. It is true that if the Put-In-Bay Caves were formed entirely by solution—and presuming that they are recent—just such cavernous features would result, for the ground water would stand at lake level and be comparatively quiet; while at Greenfield the ground water was well above local stream level, and therefore more potent. Yet this offers only a partial explanation and accounts for nothing beyond the general form of the caves.

One of the first to advance the anhydrite-gypsum theory for the origin of the Put-In-Bay Caves was E. H. Kraus (Am. Geol. XXXV, 167-71). While no trace of either anhydrite or gypsum was found in the caves, Kraus cites the occurrence of the latter in wells, surrounded by highly brecciated dolomite. The theory that the swelling of hydrated anhydrite could be great enough—either in volume or intensity—to produce caverns at first seems untenable. The conversion of anhydrite to gypsum is accompanied by a change in volume variously estimated. Credner, Fritsch, Bauer and Geikie hold the increase as low as 33%. By Nauman, Zirkel and Dana it is placed at 60%, and J. Roth has calculated it to be as high as 62%. Kraus points out that the increase of volume of water converted to ice is 9% to 10%, while the resultant force exerted

is 138 tons per square foot; and though the compressibility of gypsum is a little greater than that of water, the increase of volume, at a minimum, is more than three times as much.

The better known caves of the island—those which have been popularized by the tourist—offer much evidence in strong support of the Kraus theory. However, necessary excavations and structures, such as stairs in the entrances, have obliterated additional and possible valuable data. Partly for this reason and largely out of curiosity, two caves which hitherto had

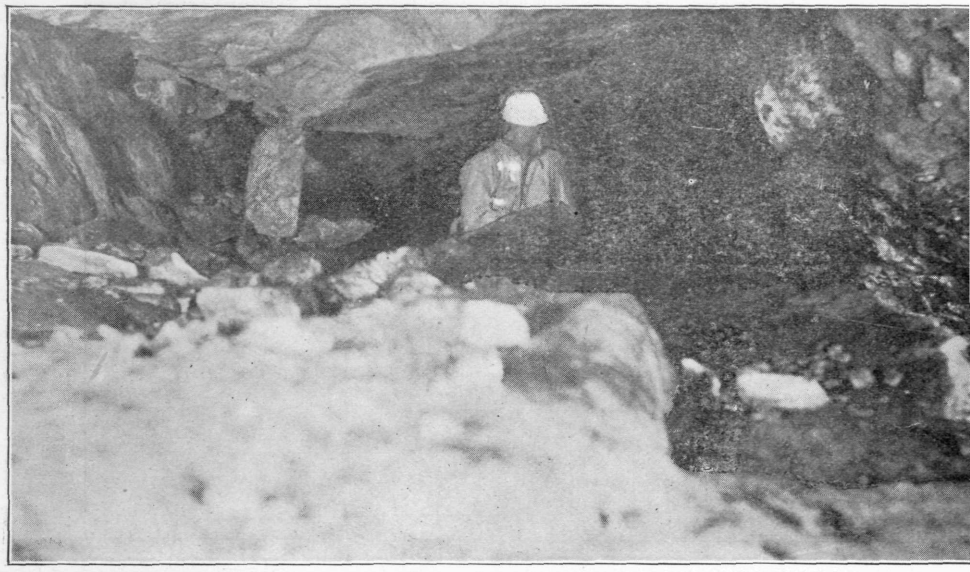


1. Lower part of Victory Cave.

drawn no attention, were explored. The first was on the property of James Duff, and the second on land held by Hotel Victory.

The entrance to the Duff Cave was under a ledge of rock, the angle of descent about 30°, direction N. 10° E., and the distance from mouth to ground water—on slope—about 60 feet. The entry is not the usual tortuous passage, but a long cleft in the rock, with average dimensions of 3′ x 150′ x 60′, terminating in an inclined chamber at ground water level about 4′ x 200′ x 35′, the floor of which is on the approximate slope of the entrance.

Corresponding layers in the floor and the roof are strikingly prominent. Unquestionably the swelling of the anhydrite caused faulting, and entrance from the surface is by way of the fault space. The throw is about four feet and the horizontal displacement about three feet. It is possible that a deeper chamber was the seat of activity, but if so it lies below lake level and the presence of water prevented exploration. No occurrence of slickensides was noted, due perhaps to the fact that the partial doming accompanying the faulting eliminated shear.

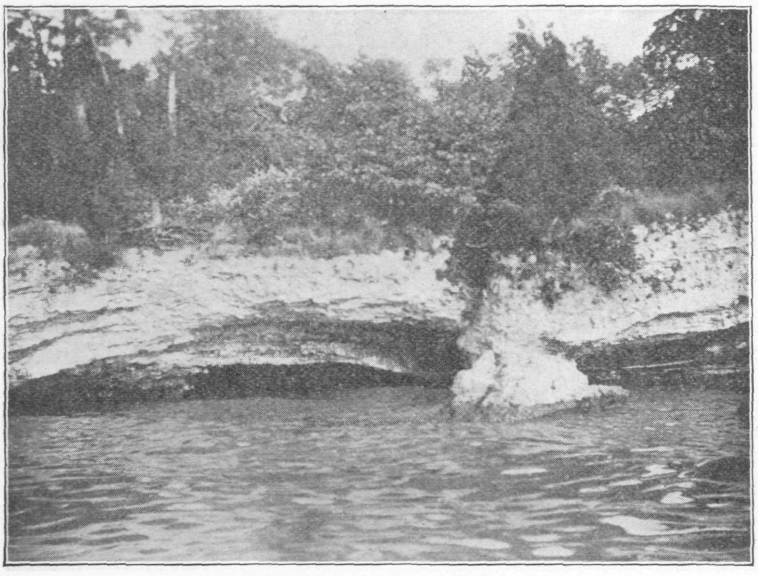


2. Duff's Cave. This lies just above ground-water level. Note correspondence in floor and roof, and degree of displacement.

Fundamentally Victory Cave is similar, differing only in proportions. The descent averages 40°, and is broken at but one point, where for a distance of fifteen feet it is vertical. From entrance to ground water level is about 150 feet, on slope. Masses of loose rock obscure true conditions. Certainly it is not a cave in the usual meaning of the term. Here again is evidence of faulting, with a throw of five feet and little or no horizontal displacement. No chamber was found—the open fault continues without a break to lake level, where the water

and detritus obstruct further exploration. It is probable that a low chamber lies below and beyond.

The numerous ledges and low bluffs of dolomite scattered about the interior of the island may be the surface expression of similar features. However, much of the island is hummocky, due to masses of outcropping rock. Whether these knolls and ledges are results of erosion or of such internal distrubances as faulting is problematical, and would only be revealed by



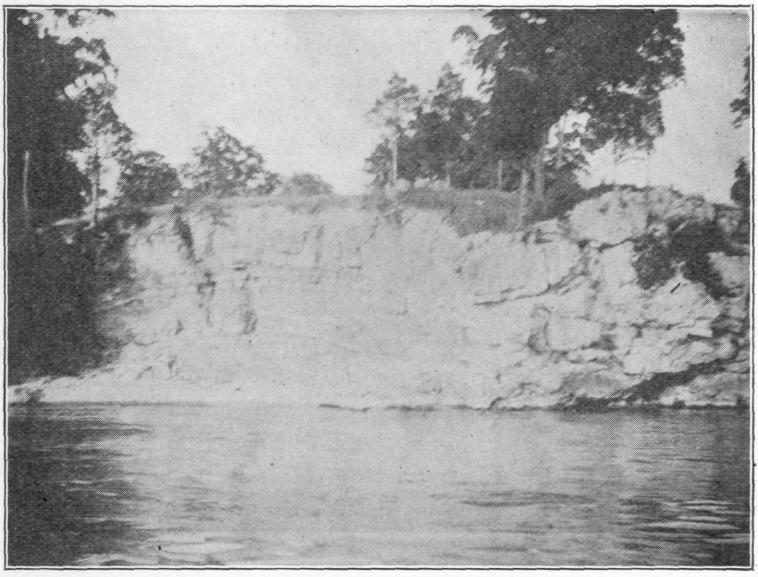
4. Characteristic shore features,
Doming and subsequent solution.

careful search. One fact arguing against solution caves is the absence of sink-holes. They are extremely rare in any case; where they do occur they are over known caves, and are due to the partial collapse of domed strata rather than collapse following solution.

Solution does occur to a limited extent. It was not found in the interior, but may be seen readily at the base of the shore cliffs, where caverns are formed at lake level. However, there has also been marked disturbance of the strata, as shown in

the shore cliffs of most of the Dolomitic islands. Of all shore caverns observed, perhaps two-thirds have resulted from doming of the roof.

There were no large stalactites or stalagmites in either Duff's or Victory Cave. Small stalactites of less than an inch in length were found in the upper part of Duff's Cave; likewise, deposition from solution has left a slight incrustation at a few points near the entrance in Victory Cave.



5. Domed Strata.

All evidence seems to confirm the Kraus view—that the caves as a class have resulted from the hydration of anhydrite, arching of overlying rock, and subsequent solution of the gypsum-filled lenses. In the two caves named above faulting was produced. Both are open, thrust faults, and entrance is gained by way of the fault space.